

Thematic Review

When the music's over. Does music skill transfer to children's and young adolescents' cognitive and academic skills? A meta-analysis



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ARTICLE INFO

Article history:

Received 10 May 2016

Received in revised form 7 November 2016

Accepted 25 November 2016

Available online 28 November 2016

Keywords:

Music training

Transfer

Cognitive skills

Education

Meta-analysis

ABSTRACT

Music training has been recently claimed to enhance children and young adolescents' cognitive and academic skills. However, substantive research on transfer of skills suggests that far-transfer - i.e., the transfer of skills between two areas only loosely related to each other - occurs rarely. In this meta-analysis, we examined the available experimental evidence regarding the impact of music training on children and young adolescents' cognitive and academic skills. The results of the random-effects models showed (a) a small overall effect size ($\bar{d} = 0.16$); (b) slightly greater effect sizes with regard to intelligence ($\bar{d} = 0.35$) and memory-related outcomes ($\bar{d} = 0.34$); and (c) an inverse relation between the size of the effects and the methodological quality of the study design. These results suggest that music training does not reliably enhance children and young adolescents' cognitive or academic skills, and that previous positive findings were probably due to confounding variables.

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1. Introduction

Recently, the question of whether music-related activities in school improve young people's cognitive and academic skills has raised much interest among researchers, educators, and policy makers. Several studies have tried to establish the effectiveness of music training in enhancing children's and young adolescents' general intelligence (Rickard, Bambrick, & Gill, 2012), memory (Roden, Kreutz, & Bongard, 2012), spatial ability and mathematics (Mehr, Schachner, Katz, & Spelke, 2013), and literacy skills (Slater et al., 2014), among others (for a review, see Miendlarzewska & Trost, 2013). Music training comprises activities such as singing songs, playing instruments, clapping, and rhythm games beyond many others. Notably, several specific curricula have been designed to develop those cognitive skills involved in playing music (e.g., Kodály method; Houlahan & Tacka, 2015). The educational implications of this research are evident. If music training enhances children's and young adolescents' cognitive skills and school grades, then schools might consider implementing additional musical activities.

1.1. The question of transfer of skills

Crucially, the importance of establishing whether music training provides any educational advantage is not limited to the field of education. In fact, this topic addresses the broader psychological question of *transfer* of skills. Transfer of learning takes place when skills learned in one particular area either generalize to new areas or increase general cognitive abilities. It is customary to distinguish between *near-* and *far-transfer* (Barnett & Ceci, 2002; Mestre, 2005). Whilst near-transfer takes place between areas that are tightly related (e.g., driving two different car models), far-transfer occurs where the relationship between source and target areas is weak (e.g., transfer from music to mathematics). Thus, postulating that music skill generalizes to other non-music-related cognitive and academic abilities means assuming the occurrence of a far-transfer.

According to Thorndike and Woodworth's (1901) common-element theory, transfer depends on the number of features that are shared between two areas; these features are hypothesized to engage common cognitive elements (Anderson, 1990). A direct consequence of this theory, well supported by empirical data in psychology and education, is that, while near-transfer should be frequent, far-transfer should be rare (Donovan, Bransford, & Pellegrino, 1999; Sala & Gobet, 2016).

1.2. Why should music skill transfer to non-music skills?

Music training has been claimed to enhance various cognitive and academic skills. Given the well-known difficulty of far-transfer to occur, it is possible that music training boosts context-independent cognitive mechanisms, which may, in turn, improve other non-music cognitive and academic skills. According to Schellenberg (2004, 2006), the most likely explanation for the alleged diverse benefits of music interventions is that such training enhances individuals' general intelligence, which correlates with many cognitive and academic skills (Deary, Strand, Smith, & Fernandes, 2007; Rohde & Thompson, 2007). Music training requires focused attention, learning complex visual patterns, memory, and fine motor skills. Thus, such a demanding activity may enhance children's and young adolescents' overall cognitive skill, which, in turn, would increase their academic performance. This hypothesis is corroborated by the fact that formal exposure to music in childhood appears to correlate with IQ scores and academic attainment (Schellenberg, 2006).

Another possible explanation relies on executive functions. Cognitive skills such as working memory, cognitive control, and cognitive flexibility are important predictors of academic achievement (e.g., Conway & Engle, 1996; Peng, Namkung, Barnes, & Sun, 2016). Learning to play an instrument engages executive functions (Bialystok & Depape, 2009; George & Coch, 2011) and it is not impossible that such improvements generalize to non-music skills.

1.3. Does music skill transfer to non-music skills? A look at the empirical evidence

Several correlational studies have shown that music skill is associated with non-music-specific skills such as literacy (Anvari, Trainor, Woodside, & Levy, 2002; Forgeard et al., 2008), mathematics (Cheek & Smith, 1999), short-term and working memory (Lee, Lu, & Ko, 2007), and general intelligence (Lynn, Wilson, & Gault, 1989; Schellenberg & Mankarious, 2012; Schellenberg, 2006). Anvari et al. (2002) found that music perception skills predicted reading abilities in preschool children. Similarly, Forgeard et al. (2008) reported that music discrimination ability correlated with phonological processing skill in a sample of typically developing and dyslexic children. Concerning mathematical ability, Cheek and Smith (1999) showed

that students who had received private lessons of music performed better in the mathematics portion of the Iowa Test of Basic Skills. Consistent with the latter two studies, [Wetter, Koerner, and Schwaninger \(2009\)](#) found a positive relationship between being engaged in music activities and overall academic achievement.

Music skill seems to be positively associated to cognitive ability too. In [Lee et al.'s \(2007\)](#) study, music-trained children and adults were compared to age-matched control groups in a series of digit span and spatial span tasks. The music-trained groups outperformed the controls in all the measures. Regarding overall cognitive ability, a convincing amount of evidence suggests that music skill and general intelligence are significantly related. [Lynn et al. \(1989\)](#) found a correlation between the scores on Raven's Standard Progressive Matrices ([Raven, 1960](#)) and a series of music tests in a group of 9–11 year-old children. Moreover, [Schellenberg \(2006\)](#) reported a positive correlation between duration of the music training and IQ in children and undergraduate students. Crucially, this result remained even after controlling for potentially confounding variables, such as parental income and education. Finally, this finding was confirmed in a more recent study involving 7- and 8-year-old children ([Schellenberg & Mankarious, 2012](#)).

However, such correlational studies cannot ascertain any far-transfer of skill from music training to other areas, because no direction of causality can be inferred. For example, both music and non-music skills could stem from innate intellectual abilities. Stronger conclusions can be drawn from studies using an experimental design, where an experimental group without previous formal musical instruction receives musical training. However, the experimental studies on the benefits of music training have provided mixed results. For example, while some studies have reported positive results ([Kaviani, Mirbaha, Pournaseh, & Sagan, 2014](#); [Portowitz, Lichtenstein, Egorova, & Brand, 2009](#)), others have showed modest evidence of music training on children's performance on intelligence tests ([Rickard et al., 2012](#); [Schellenberg, 2004](#)). Analogously, studies investigating the effect of music training on cognitive ability such as spatial- and memory-related skills have provided no clear pattern of results. For example, in [Bowels \(2003\)](#), music training exerted a strong effect on children's visuospatial ability. Analogously, in [Degé, Wehrum, Stark, and Schwarzer \(2011\)](#) music training significantly enhanced the participants' visual and auditory memory. However, [Rickard et al. \(2012\)](#) failed to find any effect in either of the above measure. With regard to academic achievement, previous meta-analyses suggest that music training slightly enhances students' mathematical ([Hetland & Winner, 2001](#); [Vaughn, 2000](#)) and literacy skills ([Gordon, Fehd, & McCandliss, 2015](#)). However, the overall effect sizes reported in these meta-analyses are modest, and the variability between studies is quite pronounced. Put simply, the effects of music training on skills such as spatial ability, memory, academic performance, and general intelligence are still controversial, and positive results have not always been replicated ([Miendlarzewska & Trost, 2013](#)).

Such variability in the results may be due to the design features of the studies, including (a) the age of the participants, (b) the random (or non-random) assignment to the treatment and control groups, and (c) the presence (or absence) of a group engaged in an alternative activity to control for non-music-specific effects, such as placebos. Age may affect the occurrence of transfer of skills in two ways. First, transfer effects may be a function of brain plasticity ([Buschkuhl, Jaeggi, & Jonides, 2012](#)), which, in turn, is a function of age. Second, as students grow up, the level of specificity of the activities they are engaged in increases (e.g., mathematics, literacy, etc.). Crucially, research on expertise has shown that the higher the level of a particular ability, the more specific the features of that ability will be, and consequently, the lower the likelihood that transfer will occur ([Ericsson & Charness, 1994](#); [Gobet, 2016](#)).

Quality design-related features may be important moderators too. Without random allocation of the participants, it is not always possible to ensure the baseline equivalence between experimental and control groups, especially if the experimental group is self-selected. Controlling for placebo effects could be even more important. In fact, the experience of a new activity such as music training may cause, *ipso facto*, an enhancement in children's and young adolescents' cognitive and academic skills. Music-related activities are usually a novelty for young students and may induce a state of motivation and excitement, which, in turn, may be the real cause of the observed (and temporary) improvements. Comparing music training with other enrichment activities is thus essential to understand whether the observed benefits are specifically due to music, or just the consequence of non-specific placebo effects.

1.4. Aims of the present meta-analysis

Because of the theoretical implications for theories of transfer, the possible educational applications, and the current general interest in this topic, it is imperative to rigorously evaluate the putative benefits of music training for academic and cognitive skills. Similar claims have been made about the possibility of obtaining transferable benefits, both cognitive and academic, from playing video-games ([Green, Li, & Bavelier, 2010](#); [Green, Pouget, & Bavelier, 2010](#)), working memory training ([Melby-Lervag & Hulme, 2013, 2016](#)), and playing chess in schools ([Gobet & Campitelli, 2006](#); [Sala & Gobet, 2016](#)). However, research in these fields suggests that optimism about the positive effects of music training must be tempered by the possibility that the observed effects are due to confounding factors such as placebo effects ([Boot, Blakely, & Simons, 2011](#); [Gobet et al., 2014](#); [Sala & Gobet, 2016](#)) and lack of random assignment of the participants to the groups.

Our meta-analysis, then, examines the potential cognitive and academic benefits of music training for the general population of children and young adolescents (see 2.2. Inclusion/Exclusion Criteria). In a first stage, we estimated the overall size of the effects of music training on non-music cognitive and academic skills by comparing experimental groups to control groups. In a second phase, we assessed the potential role of several possible moderators on the effectiveness of music training. The analysis of these factors – along with the estimation of an overall effect size – aimed to test: (a) whether music training

enhances students' cognitive and academic skills, or whether far-transfer from music to other areas is null or negligible; (b) whether music training improves some specific skills more than others; (c) whether students' age affects the benefits of music training; and (d) whether the methodological quality of the studies reviewed – i.e., random allocation of participants and comparisons with active (i.e., do-other) control groups to rule out placebo effects – influences the results.

Points a) and b) were tested by calculating a general overall effect size (see Section 3. Results) and the measure-specific overall effect sizes (see Sections 3.1 and 3.2), respectively. Points c) and d) were addressed by performing a meta-regression analyses (see Section 3.1).

2. Method

2.1. Literature search

In line with the PRISMA statement (Moher, Liberati, Tetzlaff, & Altman, 2009), a systematic search strategy was used to find the relevant studies. Using the following combination of the keywords “music” AND (“training” OR “instruction” OR “education” OR “intervention”), Google Scholar, ERIC, Psyc-Info, ProQuest Dissertation & Theses, and Scopus databases were searched to identify all the potentially relevant studies. Also, previous narrative reviews were examined, and we e-mailed researchers in the field ($n = 11$) asking for unpublished studies and inaccessible data.¹

2.2. Inclusion/Exclusion Criteria

The studies were included according to the following nine criteria:

1. The design of the study included music training; correlational and ex-post facto studies were excluded;
2. The independent variable (music training) was successfully isolated; the studies using integrated curricula (e.g., lessons of music and reading in the same intervention) were excluded;
3. The study presented a comparison between a music-treated group and, at least, one control group;
4. Music training was not merely environmental (e.g., background music, music videos);
5. During the study, a measure of academic and/or cognitive skill non-related to music was collected;
6. The participants of the study were pupils aged three to 16;
7. The participants of the study were pupils without any previous formal musical training (as stated by the authors of the included studies);
8. The participants of the study were pupils without any specific learning disability (e.g., developmental dyslexia) or clinical condition (e.g., autism);
9. The data presented in the study were sufficient to calculate an effect size.

To identify studies meeting these criteria, we searched for relevant published and unpublished articles in the last 30 years (from January 1, 1986, through March 1, 2016), and scanned reference lists.

Among the studies screened ($n = 166$), we found 38 studies, conducted from 1986 to 2016, that met all the inclusion criteria. These studies included 40 independent samples and 118 effect sizes, and a total of 3085 participants.

2.3. Moderators

We selected four potential moderators. The first two, which we termed *theoretical moderators*, referred to features of the dependent variables and the participants of the studies, while the last two, which we termed *methodological moderators*, addressed more general methodological aspects:

1. Outcome measure (categorical variable): This variable includes literacy, mathematics, memory, intelligence, phonological processing, and spatial skills.² Effect sizes that were not related to these categories (e.g., visual-auditory learning and visual attention) were labelled as *others*;
2. Age: The age of the participants in years (continuous variable);
3. Random allocation (dichotomous variable): Whether participants were fully randomly allocated to the groups;³
4. Presence of active control group (dichotomous variable): Whether the music training group was compared to another activity.

¹ Unfortunately, no author replied to our e-mails.

² These broad categories were built by aggregating different outcomes related to a particular cognitive or academic ability (e.g., reading and writing both under the category of literacy). For all the details about the dependent variables of the reviewed studies, see Table 1. See Table S1 in the Supplemental material for more details about the descriptive statistics of the studies.

³ The category of “non-random” encompasses both pre-post-test studies and only-post-test studies. Two studies reported only post-test results: Cardarelli (2003) and Geoghegan and Mitchelmore (1996).

2.4. Effect size⁴

For the studies with an *only-post-test design*, the standardized means difference (Cohen's d) was calculated with the following formula:

$$d = (M_e - M_c) / SD_{pooled} \quad (1)$$

where SD_{pooled} is the pooled standard deviation, and M_e and M_c are the means of the experimental group and the control group, respectively.⁵ For the studies with a *repeated-measure design*, the standardized means difference was calculated with the following formula:

$$d = (M_{g-e} - M_{g-c}) / SD_{pooled-pre} \quad (2)$$

where $SD_{pooled-pre}$ is the pooled standard deviation of the two pre-test standard deviations, and M_{g-e} and M_{g-c} are the gain of the experimental group and the control group, respectively (Schmidt & Hunter, 2015, p. 353).

Analogously to other recent meta-analyses (e.g., Macnamara, Hambrick, & Oswald, 2014), the effect sizes with z-scores greater than 3 ($n = 9$) or smaller than -3 ($n = 2$) were Winsorized to z-scores equal to 2.99 and -2.99 , respectively.⁶ This procedure was adopted to reduce the weight of potential outliers in the analysis (Lipsey & Wilson, 2001; Schmidt & Hunter, 2015, pp. 235–236; Tukey, 1962). Finally, the Comprehensive Meta-Analysis (Version 3.0; Biostat, Englewood, NJ) software package was used for computing the effect sizes and conducting statistical analyses.

2.5. Statistical dependence of the samples

The effect sizes were calculated for each dependent variable reported in the studies (Schmidt & Hunter, 2015). Moreover, when the study presented a comparison between one experimental group and two control groups (do-nothing and active), two effect sizes were calculated (one for each comparison with experimental and control groups; see Table 1). As this procedure violates the principle of statistical independence, the method designed by Cheung and Chan (2004) was applied to both the main and the additional models (see Sections 3.1 and 3.2). This method reduces the weight in the analysis of dependent samples by calculating an adjusted (i.e., smaller) N . Since Cheung and Chan's (2004) method cannot be used for partially dependent samples, we ran our analyses as if the comparisons between experimental samples and two different control groups were statistically independent. However, it must be noticed that the violation of statistical independence has little or no effect on means, standard deviations, and confidence intervals (Bijmolt & Pieters, 2001; Tracz, Elmore, & Pohlmann, 1992). Thus, the entire procedure is a reliable way to deal with the statistical dependence of part of the samples. For the list of the studies and the adjusted N s, see Table S2 in the Supplemental material available online.

3. Results

The random-effects meta-analytic overall effect size was $\bar{d} = 0.16$, CI [0.09; 0.22], $k = 118$, $p < 0.001$. The forest plot is shown in Fig. 1. The degree of heterogeneity (Borenstein, Hedges, Higgins, & Rothstein, 2009) between effect sizes was $I^2 = 46.94$, suggesting that some moderators had a potential effect.⁷

3.1. Meta-regression analysis

A meta-regression model including all the four moderators was run. The model fitted the data significantly, $Q(9) = 49.06$, $R^2 = 0.65$, $p < 0.001$. Age was not a significant moderator, $p = 0.944$. The statistically significant moderators were Outcome measure, $Q(6) = 21.78$, $p = 0.001$, Random allocation, $b = -0.16$, $p = 0.010$, and Presence of active control group, $b = -0.25$, $p < 0.001$. The last two moderators show that studies with random allocation of participants and studies comparing music treatment to another activity (active control group) tended to have weaker effect sizes. The overall effect sizes in randomized and non-randomized samples were $\bar{d} = 0.09$, CI [-0.01; 0.18], $k = 57$, $p = 0.084$, and $\bar{d} = 0.23$, CI [0.14; 0.31], $k = 61$, $p < 0.001$, respectively. The overall effect sizes when music training was compared to active control and do-nothing control groups were $\bar{d} = 0.03$, CI [-0.07; 0.12], $k = 54$, $p = 0.562$, and $\bar{d} = 0.25$, CI [0.17; 0.34], $k = 64$, $p < 0.001$, respectively. Finally, the overall effect size in randomized samples with active control groups was $\bar{d} = -0.12$, CI [-0.27; 0.03], $k = 22$, $p = 0.113$, while the overall effect size in the non-randomized samples without active control group was $\bar{d} = 0.33$, CI [0.23; 0.44], $k = 29$, $p < 0.001$.

⁴ All the formulas we used were taken from Schmidt and Hunter (2015).

⁵ If the t statistic was provided, we used the regular formula $d = t \times \sqrt{(n_1 + n_2) / (n_1 \times n_2)}$.

⁶ We also performed additional analyses without Winsorizing the 11 effect sizes. No significant difference was found in the overall results (for the details, see Section S1 and Table S3 in the Supplemental material available online).

⁷ A degree of heterogeneity (I^2) around 50.00 is considered moderate, around 25.00 low, and around 75.00 high.

Table 1

Studies, dependent variables, and moderators of the 118 effect sizes included in the meta-analysis.

Study	Dependent variable	Outcome measure	Age (years) ^a	Randomization	Active control group
Bhide, Power, and Goswami (2013) - M1	Working Memory (digit span)	Memory	6.8	No	Yes
Bhide et al. (2013) - M2	Phonological awareness	Phonological processing	6.8	No	Yes
Bhide et al. (2013) - M3	Spelling	Literacy	6.8	No	Yes
Bhide et al. (2013) - M4	Reading	Literacy	6.8	No	Yes
Bilhartz, Bruhn, and Olson (1999)	Intelligence (vocabulary)	Intelligence	4.5	No	No
Bowels (2003) - M1	Spatial temporal ability	Spatial	6.5	Yes	No
Bowels (2003) - M2	Reading	Reading	6.5	Yes	No
Bowels (2003) - M3	Phonological awareness	Phonological processing	6.5	Yes	No
Cardarelli (2003) - M1	Reading	Reading	9.0	No	No
Cardarelli (2003) - M2	Mathematics	Mathematics	9.0	No	No
Cogo-Moreira, de Avila, Ploubidis, and Mari (2013) - M1	Phonological awareness	Phonological processing	9.2	Yes	No
Cogo-Moreira et al. (2013) - M2	Reading	Literacy	9.2	Yes	No
Costa-Giomi (2004) - M1	Mathematics	Mathematics	9.0	Yes	No
Costa-Giomi (2004) - M2	Language	Literacy	9.0	Yes	No
Costa-Giomi (2004) - M3	Mathematics	Mathematics	9.0	Yes	No
Degé and Schwarzer (2011) - S1	Phonological awareness	Phonological processing	5.8	Yes	Yes
Degé and Schwarzer (2011) - S2	Phonological awareness	Phonological processing	5.8	Yes	No
Degé et al. (2011) - M1	Visual memory	Memory	10.8	No	No
Degé et al. (2011) - M2	Memory (auditory)	Memory	10.8	No	No
Geoghegan and Mitchelmore (1996)	Mathematics	Mathematics	4.5	No	No
Gromko (2005)	Phonemic awareness	Phonological processing	5.5	No	No
Gromko and Poorman (1998)	Intelligence	Intelligence	3.5	No	No
Hanson (2001) - M1 - S1	Intelligence	Intelligence	5.5	Yes	No
Hanson (2001) - M1 - S2	Intelligence	Intelligence	5.5	No	Yes
Hanson (2001) - M2 - S1	Spatial-temporal ability	Spatial	5.5	Yes	No
Hanson (2001) - M2 - S2	Spatial-temporal ability	Spatial	5.5	No	Yes
Hanson (2001) - M3 - S1	Spatial recognition	Spatial	5.5	Yes	No
Hanson (2001) - M3 - S2	Spatial recognition	Spatial	5.5	No	Yes
Herrera, Lorenzo, Defior, Fernandez-Smith, and Costa-Giomi (2011) - M1 - S1	Phonological awareness	Phonological processing	4.6	Yes	Yes
Herrera et al. (2011) - M2 - S1	Naming speed	Phonological processing	4.6	Yes	Yes
Herrera et al. (2011) - M1 - S2	Phonological awareness	Phonological processing	4.6	Yes	Yes
Herrera et al. (2011) - M2 - S2	Naming speed	Phonological processing	4.6	Yes	Yes
Hole (2013)	Reading	Reading	8.9	No	Yes
Hunt (2012)	Phonological discrimination	Phonological processing	3.5	Yes	No
Janus, Lee, Moreno, and Bialystok (2016) - M1	Working Memory (verbal)	Memory	5.0	No	Yes
Janus et al. (2016) - M2	Working Memory (spatial)	Memory	5.0	No	Yes
Janus et al. (2016) - M3	Executive Control (verbal fluency)	Other	5.0	No	Yes
Janus et al. (2016) - M4	Attention (sentence judgement)	Other	5.0	No	Yes
Janus et al. (2016) - M5	Attention (visual search)	Other	5.0	No	Yes
Kaviani et al. (2014) - M1	Intelligence (IQ)	Intelligence	5.5	Yes	No
Kaviani et al. (2014) - M2	Abstract reasoning	Intelligence	5.5	Yes	No
Kaviani et al. (2014) - M3	Verbal reasoning	Intelligence	5.5	Yes	No
Kaviani et al. (2014) - M4	Quantitative reasoning	Intelligence	5.5	Yes	No
Kaviani et al. (2014) - M5	Short-term memory	Memory	5.5	Yes	No
Legette (1993) - M1	Mathematics	Mathematics	6.0	No	No
Legette (1993) - M2	Reading	Reading	6.0	No	No
Lu (1986)	Reading	Reading	6.0	No	Yes
Mehr et al. (2013) - M1 - S1	Spatial navigation reasoning	Spatial	4.0	Yes	Yes
Mehr et al. (2013) - M1 - S2	Spatial navigation reasoning	Spatial	4.0	Yes	No
Mehr et al. (2013) - M2 - S1	Visual form analysis	Spatial	4.0	Yes	Yes
Mehr et al. (2013) - M2 - S2	Visual form analysis	Spatial	4.0	Yes	No
Mehr et al. (2013) - M3 - S1	Numerical discrimination	Mathematics	4.0	Yes	Yes
Mehr et al. (2013) - M3 - S2	Numerical discrimination	Mathematics	4.0	Yes	No
Mehr et al. (2013) - M4 - S1	Receptive vocabulary	Literacy	4.0	Yes	Yes
Mehr et al. (2013) - M4 - S2	Receptive vocabulary	Literacy	4.0	Yes	No
Moreno et al. (2009)	Reading	Literacy	8.3	No	Yes
Moreno, Friesen, and Bialystok (2011) - M1	Rhyming	Phonological processing	5.3	Yes	Yes
Moreno et al. (2011) - M2	Visual-auditory learning	Other	5.3	Yes	Yes
Moritz, Yampolsky, Papadelis, Thomson, and Wolf (2013) - M1	Rhyming	Phonological processing	5.6	No	No
Moritz et al. (2013) - M2	Isolation of phonemes	Phonological processing	5.6	No	No
Myant, Armstrong, and Healy (2008) - M1	Alliteration	Phonological processing	4.3	No	No
Myant et al. (2008) - M2	Rhyming	Phonological processing	4.3	No	No
Portowitz et al. (2009) - M1	Intelligence	Intelligence	8.0	No	No

Table 1 (continued)

Study	Dependent variable	Outcome measure	Age (years) ^a	Randomization	Active control group
Portowitz et al. (2009) - M2	Memory	Memory	8.0	No	No
Portowitz, Peppler, and Downton (2014)	Working Memory (spatial)	Memory	9.5	No	No
Rauscher and Zupan (2000) - M1	Working memory	Memory	5.5	No	No
Rauscher and Zupan (2000) - M2	Spatial-temporal ability	Spatial	5.5	No	No
Register (2004) - M1 - S1	Letter naming	Phonological processing	6.0	No	Yes
Register (2004) - M1 - S2	Letter naming	Phonological processing	6.0	No	No
Register (2004) - M2 - S1	Sounds fluency	Phonological processing	6.0	No	Yes
Register (2004) - M2 - S2	Sounds fluency	Phonological processing	6.0	No	No
Register (2004) - M3 - S1	Reading	Literacy	6.0	No	Yes
Register (2004) - M3 - S2	Reading	Literacy	6.0	No	No
Rickard et al. (2012) - M1 - S1	Memory	Memory	12.7	No	Yes
Rickard et al. (2012) - M1 - S2	Memory	Memory	12.7	No	Yes
Rickard et al. (2012) - M2 - S1	Intelligence (IQ)	Intelligence	12.7	No	Yes
Rickard et al. (2012) - M2 - S2	Intelligence (IQ)	Intelligence	12.7	No	Yes
Rickard et al. (2012) - M3 - S3	Reading	Literacy	10.9	Yes	Yes
Rickard et al. (2012) - M3 - S4	Reading	Literacy	10.9	Yes	No
Rickard et al. (2012) - M4 - S3	Writing	Literacy	10.9	Yes	Yes
Rickard et al. (2012) - M4 - S4	Writing	Literacy	10.9	Yes	No
Rickard et al. (2012) - M5 - S3	Speaking	Literacy	10.9	Yes	Yes
Rickard et al. (2012) - M5 - S4	Speaking	Literacy	10.9	Yes	No
Rickard et al. (2012) - M6 - S3	Space	Spatial	10.9	Yes	Yes
Rickard et al. (2012) - M6 - S4	Space	Spatial	10.9	Yes	No
Rickard et al. (2012) - M7 - S3	Number	Mathematics	10.9	Yes	Yes
Rickard et al. (2012) - M7 - S4	Number	Mathematics	10.9	Yes	No
Rickard et al. (2012) - M8 - S3	Structure	Mathematics	10.9	Yes	Yes
Rickard et al. (2012) - M8 - S4	Structure	Mathematics	10.9	Yes	No
Rickard et al. (2012) - M9 - S3	Measurement	Mathematics	10.9	Yes	Yes
Rickard et al. (2012) - M9 - S4	Measurement	Mathematics	10.9	Yes	No
Rickard et al. (2012) - M10 - S3	Mathematics	Mathematics	10.9	Yes	Yes
Rickard et al. (2012) - M10 - S4	Mathematics	Mathematics	10.9	Yes	No
Roden, Könen et al. (2014) - M1	Visual attention	Other	7.9	No	Yes
Roden, Könen et al. (2014) - M2	Speed processing	Other	7.9	No	Yes
Roden, Grube et al. (2014) - M1	Working memory (visuospatial)	Memory	7.5	No	Yes
Roden, Grube et al. (2014) - M2	Working memory (phonological)	Memory	7.5	No	Yes
Roden, Grube et al. (2014) - M3	Working memory (CE)	Memory	7.5	No	Yes
Roden et al. (2012) - M1 - S1	Verbal memory	Memory	7.7	No	Yes
Roden et al. (2012) - M1 - S2	Verbal memory	Memory	7.7	No	No
Roden et al. (2012) - M2 - S1	Visual memory	Memory	7.7	No	Yes
Roden et al. (2012) - M2 - S2	Visual memory	Memory	7.7	No	No
Schellenberg (2004) - S1	Intelligence (IQ)	Intelligence	6.0	Yes	Yes
Schellenberg (2004) - S2	Intelligence (IQ)	Intelligence	6.0	Yes	No
Schellenberg, Corrigan, Dys, and Malti (2015)	Vocabulary	Literacy	8.7	No	No
Slater et al. (2014) - M1	Reading	Reading	8.3	No	No
Slater et al. (2014) - M2	Phonological awareness	Phonological processing	8.3	No	No
Slater et al. (2014) - M3	Phonological memory	Phonological processing	8.3	No	No
Slater et al. (2014) - M4	Rapid naming	Phonological processing	8.3	No	No
Thompson, Schellenberg, and Husain (2004) - M1 - S1	Speech Prosody (spoken utterance)	Phonological processing	7.0	Yes	Yes
Thompson et al. (2004) - M1 - S2	Speech Prosody (spoken utterance)	Phonological processing	7.0	Yes	No
Thompson et al. (2004) - M2 - S1	Speech Prosody (tone sequence)	Phonological processing	7.0	Yes	Yes
Thompson et al. (2004) - M2 - S2	Speech Prosody (tone sequence)	Phonological processing	7.0	Yes	No
Tierney, Krizman, and Kraus (2015) - M1	Phonological awareness	Phonological processing	14.7	No	Yes
Tierney et al. (2015) - M2	Phonological memory	Phonological processing	14.7	No	Yes
Tierney et al. (2015) - M3	Phonological awareness	Phonological processing	14.7	No	Yes
Yazejian and Peisner-Feinberg (2009) - M1	Phoneme deletion	Phonological processing	4.4	Yes	No
Yazejian and Peisner-Feinberg (2009) - M2	Rhyming	Phonological processing	4.4	Yes	No

Note. For studies with multiple samples, the result of each sample (S1, S2, etc.) is reported separately, and for studies with multiple outcome measures, the result of each measure (M1, M2, etc.) is reported separately.

^a When the mean age was not provided, the medium range was inserted in the model. Similarly, when the grade of the students was provided the medium range was considered (e.g., first graders, six-year-olds).

3.2. Additional meta-analytic models

Since Outcome measure was a significant moderator, we calculated the random-effects meta-analytic overall effect size of each of the seven measures, in order to investigate whether any measure showed an overall effect size appreciably larger (or smaller) than the others. The overall effect sizes are summarized in Table 2.

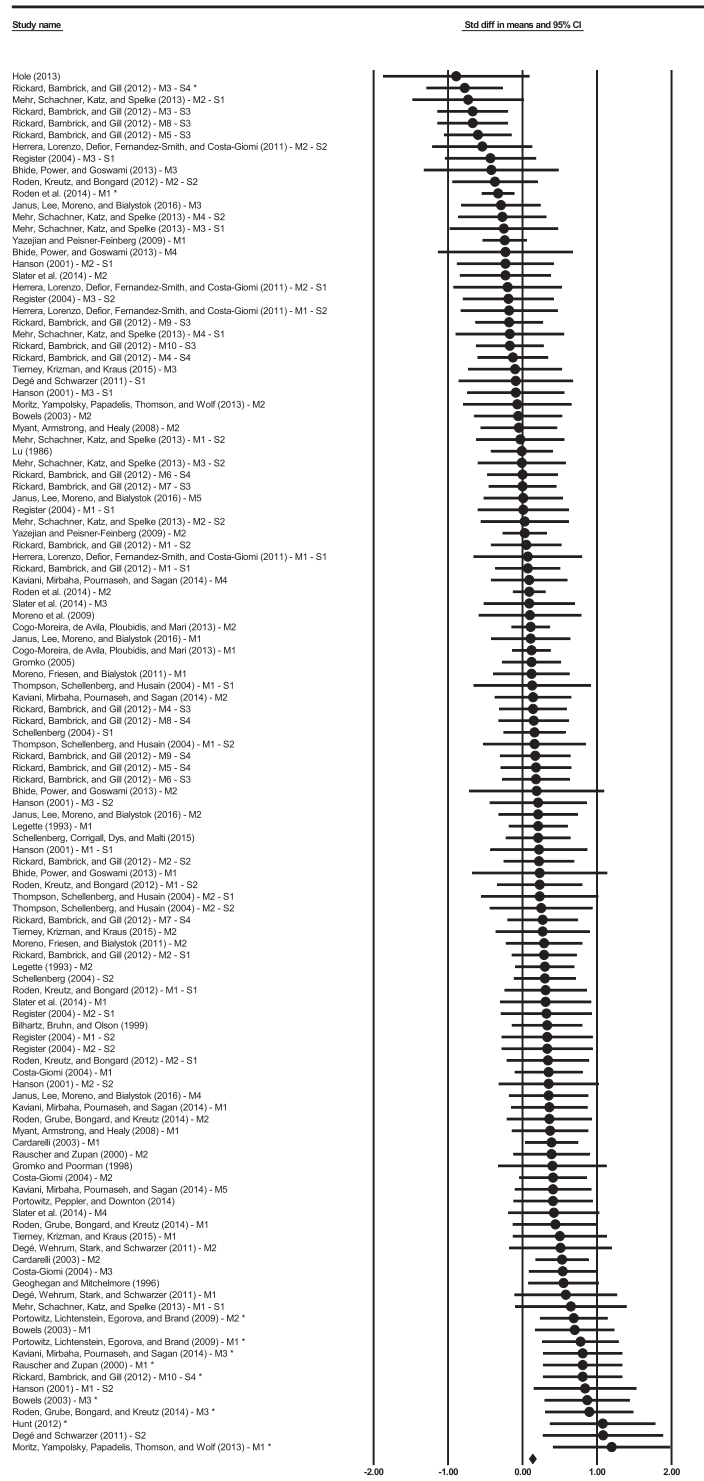


Fig. 1. Overall effect size (\bar{d}) for music training groups compared to control groups. Cohen's d s (circles) and 95% CIs (lines) are shown for all the effects entered into the meta-analysis. The diamond at the bottom indicates the meta-analytically weighted mean \bar{d} . When studies had multiple samples, the table reports the result of each sample (S1, S2, etc.) separately. Similarly, when studies used multiple outcome measures, the table reports the result of each measure (M1, M2, etc.) separately. Asterisks indicate adjusted (Winsorized) outliers.

The meta-regression analysis showed that only memory- and intelligence-related overall effect sizes were significantly different compared to the other measures ($b = 0.26$, $p = 0.041$, and $b = 0.30$, $p = 0.029$, respectively).

3.3. Publication bias analysis

Begg and Mazumdar's (1994) rank correlation test showed no evidence of publication bias ($p = 0.433$, one-tailed). In addition, to test the robustness of results (Kepes & McDaniel, 2015), we ran a p -curve analysis for the detection of publication bias (Simonsohn, Nelson, & Simmons, 2014). We selected the p s according the following two rules: (a) only positive results (i.e., $z > 0$) were considered; and (b) to avoid redundancy, only one $p < 0.01$ per study was inserted into the analysis. The results had evidential value (i.e., no evidence of publication bias) because we found more low p -values ($p < 0.01$) than high p -values ($0.01 < p < 0.05$), $z(14) = -4.24$, $p < 0.001$ (Fig. 2).

Finally, Duval and Tweedie's (2000) method found no publication bias in any of the seven models (i.e., no studies trimmed left of the mean).

3.4. Sensitivity analysis

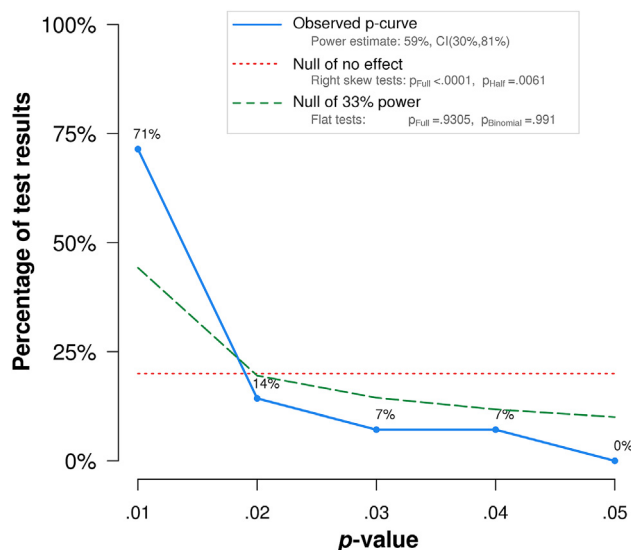
Since Rickard et al.'s (2012) study reported a large number of effect sizes ($k = 20$), we conducted a sensitivity analysis by excluding those effect sizes from all the models. The random-effects meta-analytic overall effect size was still modest, $\bar{d} = 0.20$, CI [0.14; 0.27], $k = 98$, $p < 0.001$. The degree of heterogeneity between effect sizes was $I^2 = 39.31$, suggesting that some moderators had a potential effect. For the list of the studies and the adjusted N s, see Table S4 in the Supplemental material available online.

A meta-regression model including all the four moderators was run. The model fitted the data significantly, $Q(9) = 36.94$, $R^2 = 0.74$, $p < 0.001$. The only two statistically significant moderators were Outcome measure, $Q(6) = 20.16$, $p = 0.003$ and Presence of active control group, $b = -0.17$, $p = 0.014$. The overall effect sizes when music training was compared to do-

Table 2

Overall effect sizes, confidence intervals, k s, and p -values in each outcome measure.

Outcome measure	Effect size (\bar{d})	95% CI	k	p -value
Literacy	-0.07	[-0.23; 0.09]	22	0.386
Mathematics	0.17	[-0.02; 0.36]	15	0.085
Memory	0.34	[0.20; 0.48]	18	<0.001
Intelligence	0.35	[0.21; 0.49]	13	<0.001
Phonological processing	0.17	[0.04; 0.29]	32	0.008
Spatial	0.14	[-0.06; 0.34]	12	0.168
Others	-0.01	[-0.25; 0.23]	6	0.919



Note: The observed p-curve includes 14 statistically significant ($p < 0.05$) results, of which 13 are $p < 0.025$. There were no non-significant results entered.

Fig. 2. p -curve analysis of the studies reporting significantly positive results. The blue line shows that most of the significant p -values are smaller than 0.01. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

nothing control and active control groups were $\bar{d} = 0.28$, CI [0.19; 0.36], $k = 56$, $p < 0.001$, and $\bar{d} = 0.08$, CI [−0.03; 0.19], $k = 42$, $p = 0.139$, respectively. Compared to Table 2, no significant difference was found in six of the seven Outcome measure-related overall effect sizes. The only exception was Mathematics ($\bar{d} = 0.35$ vs $\bar{d} = 0.17$; Table 3).

4. Discussion

The present meta-analysis aimed to test the hypothesis that music training improves children's and young adolescents' cognitive and academic skills, and to evaluate the potential role of moderating variables. Along with a small overall effect size ($\bar{d} = 0.16$, CI [0.09; 0.22]), which indicates that far-transfer from music to non-music skills was limited, the results showed a slightly greater positive effect of music training on some of the cognitive skills (i.e., intelligence and memory) and a non-significant effect on all the academic skills. Moreover, the design quality of the studies significantly affected the magnitude of the effects. A similar pattern of results was obtained in the sensitivity analysis model.

We did not correct for attenuation due to measurement error because only about half of the studies provided reliability coefficients. However, correcting for measurement error would not significantly affect the effect sizes. For example, if we assume that the reliability coefficients are between 0.80 and 0.90, then the corrected estimate of the overall effect size of the main model (i.e., $\bar{d} = 0.16$) would be between 0.17 and 0.18, a difference of only 0.01 or 0.02 standard deviations.

4.1. Substantive results

The outcomes of the present meta-analysis allow us to draw some important conclusions. First, the small overall effect size upholds Thorndike and Woodworth's (1901) common-element theory. In line with previous research (Donovan et al., 1999; Sala & Gobet, 2016), far-transfer from music to other cognitive or academic abilities seems to be small or null. Second, music training appears to moderately foster intelligence- and memory-related outcomes. However, no significant effect on academic skills was found (literacy, $\bar{d} = -0.07$, CI [−0.23; 0.09], $p = 0.386$; mathematics, $\bar{d} = 0.17$, CI [−0.02; 0.36], $p = 0.085$). This outcome suggests that improvements in memory and intelligence do not generalize to academic skills. Alternatively, and more likely, the observed positive effects of music training in intelligence- and memory-related outcomes are due to confounding variables (we will take up this point below). Either way, the hypothesis according to which the multiple benefits of music training, including academic benefits, stem from an improvement in general intelligence (or overall cognitive skill) is not corroborated. Third, the age of the participants is not a statistically significant moderator. Fourth, the meta-regression model accounts for a large proportion of the variance ($R^2 = 0.65$) between the effect sizes. The latter result implies that the statistically significant moderators explain, to a large extent, why the research on the effects of music training on children's and young adolescents' skills has produced mixed results up to now.

4.2. Methodological results

The meta-regression analysis shows that both methodological moderators (i.e., random allocation of participants to the treatment groups and comparison to an active control group) affected the effect sizes. In other words, the better the design quality, the smaller the effect sizes. This outcome lends further support to the idea that the observed positive effects, when any, of music training on non-music-related outcomes are probably due to confounding variables, such as placebo effects and lack of random allocation of participants.

Unfortunately, this conclusion seems to apply to memory- and intelligence-related effect sizes too. In fact, despite the greater overall effect sizes in these two outcome measures ($\bar{d} = 0.34$, CI [0.20; 0.48] and $\bar{d} = 0.35$, CI [0.21; 0.49], respectively), the reliability of these positive results seems questionable. Only one study (Schellenberg, 2004) tested the effect of music training on children's intelligence using a rigorous experimental design (i.e., random allocation of participants and active control group), and the effect was found to be modest ($d = 0.16$). Concerning the memory-related outcomes, none of the reviewed studies adopted such a design. Furthermore, as pointed out above, a genuine – i.e., not due to confounding variables – improvement in such critical cognitive skills should leave a trace in students' academic skills, at least to some degree.

The sensitivity analysis (Section 3.4) showed that when Rickard et al.'s (2012) study and all its effect sizes were excluded, the overall effect size in mathematics became significantly positive. However, the only study comparing a music training

Table 3
Overall effect sizes, confidence intervals, ks, and p-values in each outcome measure.

Outcome measure	Effect size (\bar{d})	95% CI	k	p-value
Literacy	0.07	[−0.07; 0.21]	16	0.307
Mathematics	0.35	[0.16; 0.54]	7	<0.001
Memory	0.39	[0.25; 0.54]	16	<0.001
Intelligence	0.37	[0.21; 0.53]	11	<0.001
Phonological Processing	0.17	[0.04; 0.29]	32	0.008
Spatial	0.15	[−0.10; 0.40]	10	0.248
Others	−0.01	[−0.25; 0.23]	6	0.919

Note. The 20 effect sizes calculated from Rickard et al. (2012) were excluded.

group to an active control group and with random allocation of the participants to the groups – i.e., Mehr et al. (2013) – found a negative effect size ($d = -0.25$). These considerations uphold the conclusion that music training does not substantially enhance any non-music-related cognitive skill.

4.3. Conclusions and recommendations for future research

The results of this meta-analysis fail to support the hypothesis that music skill transfers to cognitive or academic skills in the general population of children and young adolescents. Together with previous findings in psychology and education, these results suggest a sobering conclusion: when the potential occurrence of far-transfer is tested rigorously, the results are often, if not always, disappointing. Thus, this study lends further support to the hypothesis according to which far-transfer rarely occurs. Even when music training appears to foster some of the participants' cognitive skills (intelligence and memory), the reliability of the results is doubtful. In fact, only one study investigated, with a proper design, the effects exerted by music training on the participants' intelligence- and memory-related skills.

Due to the lack of well-designed studies, the question of whether music training enhances children's and young adolescents' intelligence- and memory-related skills is still unanswered. For this reason, future studies should strive for proper designs that include both random allocation of the participants and an active control group. Furthermore, future investigations should evaluate the effects of music training on both cognitive (especially intelligence and memory) and academic skills. Such a design makes it possible to empirically assess whether the potential benefits of music training on youngsters' cognitive skills generalize to academic performance. Nonetheless, considering the previous unsatisfactory outcomes and the scarcity of far-transfer in the literature, it is our opinion that future experiments will show results in line with those presented in this meta-analysis.

Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.edurev.2016.11.005>.

References⁸

- Anderson, J. R. (1990). *Cognitive psychology and its implications* (3rd ed.). New York: Freeman & Cie.
- Anvari, S. H., Trainor, L. G., Woodside, J., & Levy, B. A. (2002). Relations among musical skills, phonological processing, and early reading ability in preschool children. *Journal of Experimental Child Psychology*, 83, 111–130. [http://dx.doi.org/10.1016/S0022-0965\(02\)00124-8](http://dx.doi.org/10.1016/S0022-0965(02)00124-8).
- Barnett, S. M., & Ceci, S. J. (2002). When and where do we apply what we learn? A taxonomy for far transfer. *Psychological Bulletin*, 128, 612–637. <http://dx.doi.org/10.1037/0033-2909.128.4.612>.
- Begg, C. B., & Mazumdar, M. (1994). Operating characteristics of a rank order correlation for publication bias. *Biometrics*, 50, 1088–1101. <http://dx.doi.org/10.2307/2533446>.
- *Bhide, A., Power, A., & Goswami, U. (2013). A rhythmic musical intervention for poor readers: A comparison of efficacy with a letter-based intervention. *Mind, Brain, and Education*, 7, 113–123. <http://dx.doi.org/10.1111/mbe.12016>.
- Bialystok, E., & Depape, A. M. (2009). Musical expertise, bilingualism, and executive functioning. *Journal of Experimental Psychology: Human Perception and Performance*, 35, 565–574. <http://dx.doi.org/10.1037/a0012735>.
- Bijmolt, T. H. A., & Pieters, R. G. M. (2001). Meta-analysis in marketing when studies contain multiple measurements. *Marketing Letters*, 12, 157–169. <http://dx.doi.org/10.1023/A:1011117103381>.
- *Bilhart, T. D., Bruhn, R. A., & Olson, J. E. (1999). The effect of early music training on child cognitive development. *Journal of Applied Developmental Psychology*, 20, 615–636. [http://dx.doi.org/10.1016/S0193-3973\(99\)00033-7](http://dx.doi.org/10.1016/S0193-3973(99)00033-7).
- Boot, W. R., Blakely, D. P., & Simons, D. J. (2011). Do action video games improve perception and cognition? *Frontiers in Psychology*, 2, 226. <http://dx.doi.org/10.3389/fpsyg.2011.00226>.
- Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2009). *Introduction to meta-analysis*. London: Wiley.
- *Bowels, S. M. (2003). *Tune up the mind: The effect of orchestrating music as a reading intervention*. Doctoral dissertation. PA: Indiana: Indiana University of Pennsylvania.
- Buschkuhl, M., Jaeggi, S. M., & Jonides, J. (2012). Neuronal effects following working memory training. *Developmental Cognitive Neuroscience*, 2(Suppl. 1), S167–S179. <http://dx.doi.org/10.1016/j.dcn.2011.10.001>.
- *Cardarelli, D. M. (2003). *The effects of music instrumental training on performance on the reading and mathematics portions of the Florida Comprehensive Achievement test for third grade students*. Doctoral dissertation. FL: Orlando: University of Central Florida.
- Cheek, J. M., & Smith, L. R. (1999). Music training and mathematics achievement. *Adolescence*, 34, 759–761.
- Cheung, S. F., & Chan, D. K. S. (2004). Dependent effect sizes in meta-analysis: Incorporating the degree of interdependence. *Journal of Applied Psychology*, 89, 780–791. <http://dx.doi.org/10.1037/0021-9010.89.5.780>.
- *Cogo-Moreira, H., de Avila, C. R. B., Ploubidis, G. B., & Mari, J. D. (2013). Effectiveness of music education for the improvement of reading skills and academic achievement in young poor readers: A pragmatic cluster-randomized, controlled clinical trial. *PLoS ONE*, 8. <http://dx.doi.org/10.1371/journal.pone.0059984>.
- Conway, A. R. A., & Engle, R. W. (1996). Individual differences in working memory capacity: More evidence for a general capacity theory. *Memory*, 4, 577–590. <http://dx.doi.org/10.1080/741940997>.
- *Costa-Giomi, E. (2004). Effects of three years of piano instruction on children's academic achievement, school performance and self-esteem. *Psychology of Music*, 32, 139–152. <http://dx.doi.org/10.1177/0305735604041491>.
- Deary, I. J., Strand, S., Smith, P., & Fernandes, C. (2007). Intelligence and educational achievement. *Intelligence*, 35, 13–21. <http://dx.doi.org/10.1016/j.intell.2006.02.001>.
- *Degé, F., & Schwarzer, G. (2011). The effect of a music program on phonological awareness in preschoolers. *Frontiers in Psychology*, 2. <http://dx.doi.org/10.3389/fpsyg.2011.00124>.

⁸ References marked with an asterisk indicate studies included in the meta-analysis.

- *Dégé, F., Wehrum, S., Stark, R., & Schwarzer, G. (2011). The influence of two years of school music training in secondary school on visual and auditory memory. *European Journal of Developmental Psychology*, 8, 608–623. <http://dx.doi.org/10.1080/17405629.2011.590668>.
- Donovan, M. S., Bransford, J. D., & Pellegrino, J. W. (1999). *How people learn: Bridging research and practice*. Washington, DC: National Academy Press.
- Duval, S., & Tweedie, R. (2000). Trim and fill: A simple funnel plot based method of testing and adjusting for publication bias in meta-analysis. *Biometrics*, 56, 455–463. <http://dx.doi.org/10.1111/j.0006-341X.2000.00455.x>.
- Ericsson, K. A., & Charness, N. (1994). Expert performance: Its structure and acquisition. *American Psychologist*, 49, 725–747. <http://dx.doi.org/10.1037/0003-066X.49.8.725>.
- Forgeard, M., Schlaug, G., Norton, A., Rosam, C., Iyengar, U., & Winner, E. (2008). The relation between music and phonological processing in normal-reading children and children with dyslexia. *Music Perception*, 25, 383–390. <http://dx.doi.org/10.1525/MP.2008.25.4.383>.
- *Geoghegan, N., & Mitchelmore, M. (1996). Possible effects of early childhood music on mathematical achievement. *Journal for Australian Research in Early Childhood Education*, 1, 57–64.
- George, E. M., & Coch, D. (2011). Music training and working memory: An ERP study. *Neuropsychologia*, 49, 1083–1094. <http://dx.doi.org/10.1016/j.neuropsychologia.2011.02.001>.
- Gobet, F. (2016). *Understanding expertise: A multi-disciplinary approach*. London: Palgrave/Macmillan.
- Gobet, F., & Campitelli, G. (2006). Education and chess: A critical review. In T. Redman (Ed.), *Chess and education: Selected essays from the Koltanowski conference* (pp. 124–143). Dallas, TX: Chess Program at the University of Texas at Dallas.
- Gobet, F., Johnston, S. J., Ferrufino, G., Jones, M. B., Johnston, M., Molyneux, A., ... Weeden, L. (2014). 'No level up!': No effects of video game specialization and expertise on cognitive performance. *Frontiers in Psychology*, 5. <http://dx.doi.org/10.3389/fpsyg.2014.01337>.
- Gordon, R. L., Fehd, H. M., & McCandliss, B. D. (2015). Does music training enhance literacy skills? A meta-analysis. *Frontiers in Psychology*, 6. <http://dx.doi.org/10.3389/fpsyg.2015.01777>.
- Green, C. S., Li, R. J., & Bavelier, D. (2010). Perceptual learning during action video game playing. *Topics in Cognitive Science*, 2, 202–216. <http://dx.doi.org/10.1111/j.1756-8765.2009.01054.x>.
- Green, C. S., Pouget, A., & Bavelier, D. (2010). Improved probabilistic inference as a general learning mechanism with action video games. *Current Biology*, 20, 1573–1579. <http://dx.doi.org/10.1016/j.cub.2010.07.040>.
- *Gromko, J. E. (2005). The effect of music instruction on phonemic awareness in beginning readers. *Journal of Research in Music Education*, 53, 199–209. <http://dx.doi.org/10.1177/002242940505300302>.
- *Gromko, J. E., & Poorman, A. S. (1998). The effect of music training on preschoolers' spatial-temporal task performance. *Journal of Research in Music Education*, 46, 173–181. <http://dx.doi.org/10.2307/3345621>.
- *Hanson, M. K. (2001). *An investigation of the effects of sequenced Kodaly literacy-based music instruction on the spatial reasoning skills of kindergarten students* (Unpublished manuscript).
- *Herrera, L., Lorenzo, O., Defior, S., Fernandez-Smith, G., & Costa-Giomi, E. (2011). Effects of phonological and musical training on the reading readiness of native- and foreign-Spanish-speaking children. *Psychology of Music*, 39, 68–81. <http://dx.doi.org/10.1177/0305735610361995>.
- Hetland, L., & Winner, E. (2001). The arts and academic achievement: What the evidence shows. *Arts Education Policy Review*, 102, 3–6. <http://dx.doi.org/10.1080/10632910109600008>.
- *Hole, K. A. (2013). *The impact of an auditory training programme (The Listening Programme®) on the auditory processing and reading skills of mainstream school children* (Unpublished manuscript).
- Houlihan, M., & Tacka, P. (2015). *Kodály today: A cognitive approach to elementary music education inspired by the kodály concept*. New York, NY: Oxford University Press.
- *Hunt, A. (2012). *Have you brought your singing voice?" an investigation into whether a small group singing intervention can improve phonological discrimination in young children*. Doctoral dissertation. UK: Cardiff: Cardiff University.
- *Janus, M., Lee, Y., Moreno, S., & Bialystok, E. (2016). Effects of short-term music and second-language training on executive control. *Journal of Experimental Child Psychology*, 144, 84–97. <http://dx.doi.org/10.1016/j.jecp.2015.11.009>.
- *Kaviani, H., Mirbaha, H., Pournaseh, M., & Sagan, O. (2014). Can music lessons increase the performance of preschool children in IQ tests? *Cognitive Processing*, 15, 77–84. <http://dx.doi.org/10.1007/s10399-013-0574-0>.
- Kepes, S., & McDaniel, M. A. (2015). The validity of conscientiousness is overestimated in the prediction of job performance. *PLoS ONE*, 10, e0141468. <http://dx.doi.org/10.1371/journal.pone.0141468>.
- Lee, Y., Lu, M., & Ko, H. (2007). Effect of skill training on working memory capacity. *Learning and Instruction*, 17, 336–344. <http://dx.doi.org/10.1016/j.learninstruc.2007.02.010>.
- *Legette, R. M. (1993). *The effect of a selected use of music instruction on the self-concept and academic achievement of elementary public school students*. Doctoral dissertation. FL: Tallahassee: The Florida State University School of Music.
- Lipsey, M. W., & Wilson, D. B. (2001). *Practical meta-analysis*. Thousand Oaks, CA: Sage.
- *Lu, D. T. (1986). *The effect of teaching music skills on the development of reading skills among first graders: An experimental study*. Doctoral dissertation. WA: Seattle: University of Washington.
- Lynn, R., Wilson, R. G., & Gault, A. (1989). Simple musical tests as measures of Spearman's g. *Personality and Individual Differences*, 10, 25–28. [http://dx.doi.org/10.1016/0191-8869\(89\)90173-6](http://dx.doi.org/10.1016/0191-8869(89)90173-6).
- Macnamara, B. N., Hambrick, D. Z., & Oswald, F. L. (2014). Deliberate practice and performance in music, games, sports, education, and professions: a meta-analysis. *Psychological Science*, 25, 1608–1618. <http://dx.doi.org/10.1177/0956797614535810>.
- *Mehr, S. A., Schachner, A., Katz, R. C., & Spelke, E. S. (2013). Two randomized trials provide no consistent evidence for nonmusical cognitive benefits of brief preschool music enrichment. *PLoS ONE*, 8. <http://dx.doi.org/10.1371/journal.pone.0082007>.
- Melby-Lervag, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology*, 49, 270–291. <http://dx.doi.org/10.1037/a0028228>.
- Melby-Lervag, M., & Hulme, C. (2016). There is no convincing evidence that working memory training is effective: A reply to Au et al. (2014) and karbach and verhaeghen (2014). *Psychonomic Bulletin & Review*, 23, 324–330. <http://dx.doi.org/10.3758/s13423-015-0862-z>.
- Mestre, J. P. (2005). *Transfer of learning from a modern multidisciplinary perspective*. Greenwich, CT: Information Age.
- Miendlarzewska, E. A., & Trost, W. J. (2013). How musical training affects cognitive development: Rhythm, reward and other modulating variables. *Frontiers in Neuroscience*, 7. <http://dx.doi.org/10.3389/fnins.2013.00279>.
- Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Annals of Internal Medicine*, 151, 264–269. <http://dx.doi.org/10.7326/0003-4819-151-4-200908180-00135>.
- *Moreno, S., Friesen, D., & Bialystok, E. (2011). Effect of music training on promoting preliterate skills: Preliminary causal evidence. *Music Perception*, 29, 165–172. <http://dx.doi.org/10.1525/mp.2011.29.2.165>.
- *Moreno, S., Marques, C., Santos, A., Santos, M., Castro, S. L., & Besson, M. (2009). Musical training influences linguistic abilities in 8-year-old children: More evidence for brain plasticity. *Cerebral Cortex*, 19, 712–723. <http://dx.doi.org/10.1093/cercor/bhn120>.
- *Moritz, C., Yampolsky, S., Papadelis, G., Thomson, J., & Wolf, M. (2013). Links between early rhythm skills, musical training, and phonological awareness. *Reading and Writing*, 26, 739–769. <http://dx.doi.org/10.1007/s11145-012-9389-0>.
- *Myant, M., Armstrong, W., & Healy, N. (2008). Can music make a difference? A small scale longitudinal study into the effects of music instruction in nursery on later reading ability. *Educational and Child Psychology*, 25, 83–100.
- Peng, P., Namkung, J., Barnes, M., & Sun, C. Y. (2016). A meta-analysis of mathematics and working memory: Moderating effects of working memory domain, type of mathematics skill, and sample characteristics. *Journal of Educational Psychology*, 108, 455–473. <http://dx.doi.org/10.1037/edu0000079>.

- *Portowitz, A., Lichtenstein, O., Egorova, L., & Brand, E. (2009). Underlying mechanisms linking music education and cognitive modifiability. *Research Studies in Music Education*, 31, 107–128. <http://dx.doi.org/10.1177/1321103X09344378>.
- *Portowitz, A., Peppler, K. A., & Downton, M. (2014). In harmony: A technology-based music education model to enhance musical understanding and general learning skills. *International Journal of Music Education*, 32, 242–260. <http://dx.doi.org/10.1177/0255761413517056>.
- *Rauscher, F. H., & Zupan, M. A. (2000). Classroom keyboard instruction improves kindergarten children's spatial-temporal performance: A field experiment. *Early Childhood Research Quarterly*, 15, 215–228. [http://dx.doi.org/10.1016/S0885-2006\(00\)00050-8](http://dx.doi.org/10.1016/S0885-2006(00)00050-8).
- Raven, J. (1960). *Guide to the standard progressive matrices*. London: H. K. Lewis.
- *Register, D. (2004). The effects of live music groups versus an educational children's television program on the emergent literacy of young children. *Journal of Music Therapy*, 41, 2–27. <http://dx.doi.org/10.1093/jmt/41.1.2>.
- *Rickard, N. S., Bambrick, C. J., & Gill, A. (2012). Absence of widespread psychosocial and cognitive effects of school-based music instruction in 10–13-year-old students. *International Journal of Music Education*, 30, 57–78. <http://dx.doi.org/10.1177/0255761411431399>.
- *Roden, I., Grube, D., Bongard, S., & Kreutz, G. (2014). Does music training enhance working memory performance? Findings from a quasi-experimental longitudinal study. *Psychology of Music*, 42, 284–298. <http://dx.doi.org/10.1177/0305735612471239>.
- *Roden, I., Könen, T., Bongard, S., Frankenberg, E., Friedrich, E. K., & Kreutz, G. (2014). Effects of music training on attention, processing speed and cognitive music abilities – findings from a longitudinal study. *Applied Cognitive Psychology*, 28, 545–557. <http://dx.doi.org/10.1002/acp.3034>.
- *Roden, I., Kreutz, G., & Bongard, S. (2012). Effects of a school-based instrumental music program on verbal and visual memory in primary school children: A longitudinal study. *Frontiers in Psychology*, 3. <http://dx.doi.org/10.3389/fpsyg.2012.00572>.
- Rohde, T. E., & Thompson, L. A. (2007). Predicting academic achievement with cognitive ability. *Intelligence*, 35, 83–92. <http://dx.doi.org/10.1016/j.intell.2006.05.004>.
- Sala, G., & Gobet, F. (2016). Do the benefits of chess instruction transfer to academic and cognitive skills? A meta-analysis. *Educational Research Review*, 18, 46–57. <http://dx.doi.org/10.1016/j.edurev.2016.02.002>.
- *Schellenberg, E. G. (2004). Music lessons enhance IQ. *Psychological Science*, 15, 511–514. <http://dx.doi.org/10.1111/j.0956-7976.2004.00711.x>.
- Schellenberg, E. G. (2006). Long-term positive associations between music lessons and IQ. *Journal of Educational Psychology*, 98, 457–468. <http://dx.doi.org/10.1037/0022-0663.98.2.457>.
- *Schellenberg, E. G., Corrigan, K. A., Dys, S. P., & Malti, T. (2015). Group music training and children's prosocial skills. *PLoS ONE*, 10. <http://dx.doi.org/10.1371/journal.pone.0141449>.
- Schellenberg, E. G., & Mankarious, M. (2012). Music training and emotion comprehension in childhood. *Emotion*, 12, 887–891. <http://dx.doi.org/10.1037/a0027971>.
- Schmidt, F. L., & Hunter, J. E. (2015). *Methods of meta-analysis: Correcting error and bias in research findings* (3rd ed.). Newbury Park, CA: Sage.
- Simonsohn, U., Nelson, L. D., & Simmons, J. P. (2014). p-Curve and effect size correcting for publication bias using only significant results. *Perspectives on Psychological Science*, 9, 666–681. <http://dx.doi.org/10.1177/1745691614553988>.
- *Slater, J., Strait, D. L., Skoe, E., O'Connell, S., Thompson, E., & Kraus, N. (2014). Longitudinal effects of group music instruction on literacy skills in low-income children. *PLoS ONE*, 9. <http://dx.doi.org/10.1371/journal.pone.0113383>.
- *Thompson, W. F., Schellenberg, E. G., & Husain, G. (2004). Decoding speech prosody: Do music lessons help? *Emotion*, 4, 46–64. <http://dx.doi.org/10.1037/1528-3542.4.1.46>.
- Thorndike, E. L., & Woodworth, R. S. (1901). The influence of improvement in one mental function upon the efficiency of other functions (I). *Psychological Review*, 8, 247–261. <http://dx.doi.org/10.1037/h0074898>.
- *Tierney, A. T., Krizman, J., & Kraus, N. (2015). Music training alters the course of adolescent auditory development. *PNAS*, 112, 10062–10067. <http://dx.doi.org/10.1073/pnas.1505114112>.
- Tracz, S. M., Elmore, P. B., & Pohlmann, J. T. (1992). Correlational meta-analysis: Independent and nonindependent cases. *Educational and Psychological Measurement*, 52, 879–888. <http://dx.doi.org/10.1177/0013164492052004007>.
- Tukey, J. W. (1962). The future of data analysis. *The Annals of Mathematical Statistics*, 33, 1–67. <http://dx.doi.org/10.1214/aoms/1177704711>.
- Vaughn, K. (2000). Music and mathematics: Modest support for the oft-claimed relationship. *Journal of Aesthetic Education*, 34, 149–166. <http://dx.doi.org/10.2307/3333641>.
- Wetter, O. E., Koerner, F., & Schwaninger, A. (2009). Does musical training improve music performance? *Instructional Science*, 37, 365–374. <http://dx.doi.org/10.1007/s11251-008-9052-y>.
- *Yazejian, N., & Peisner-Feinberg, E. S. (2009). Effects of a preschool music and movement curriculum on children's language skills. *NHSA Dialog*, 12, 327–341. <http://dx.doi.org/10.1080/15240750903075255>.